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(71) Applicant
Timex Corporation
Waterbury
Connecticut 06720
United States of America
(72) Inventor
Alan Martin Garber
(74) Agents
Stevens Hewlett & Perkins

(54) Liquid crystal display

(57) A liquid crystal display comprises a substrate 11 having a non-segmented counter electrode 15 and a spaced substrate 10 having transparent segments 12 and associated uninsulated leads 12*a* together defining a second smaller electrode area overlapped by the counter electrode. Importantly, each of the overlapped leads has a width not exceeding .001 inch so that although an electric field may activate the display in said overlap, the optical effect is not visible to the unaided eye. Thus, the counter electrode 15 can be provided by simple deposition without being patterned or etched or precisely aligned.

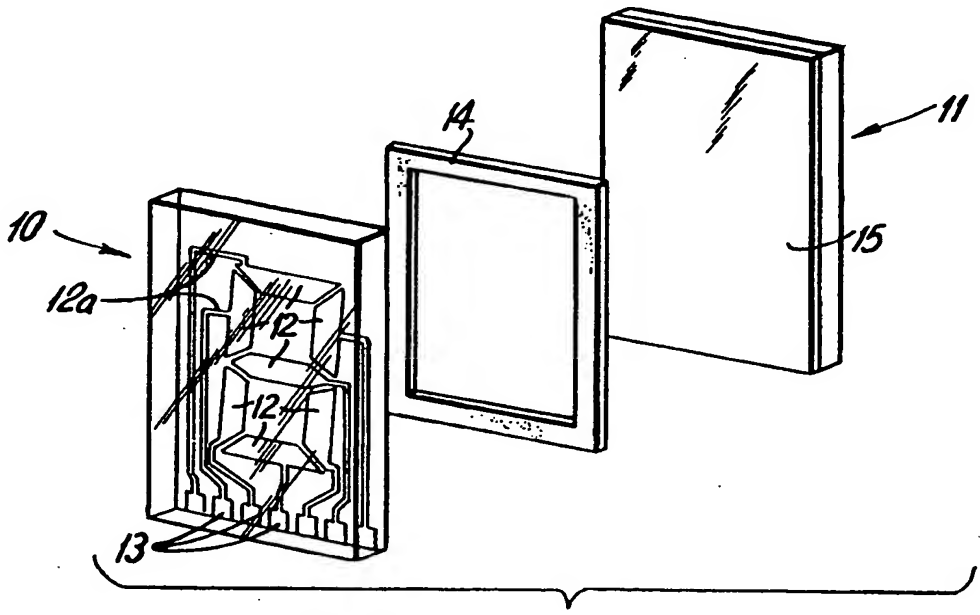

FIG.1

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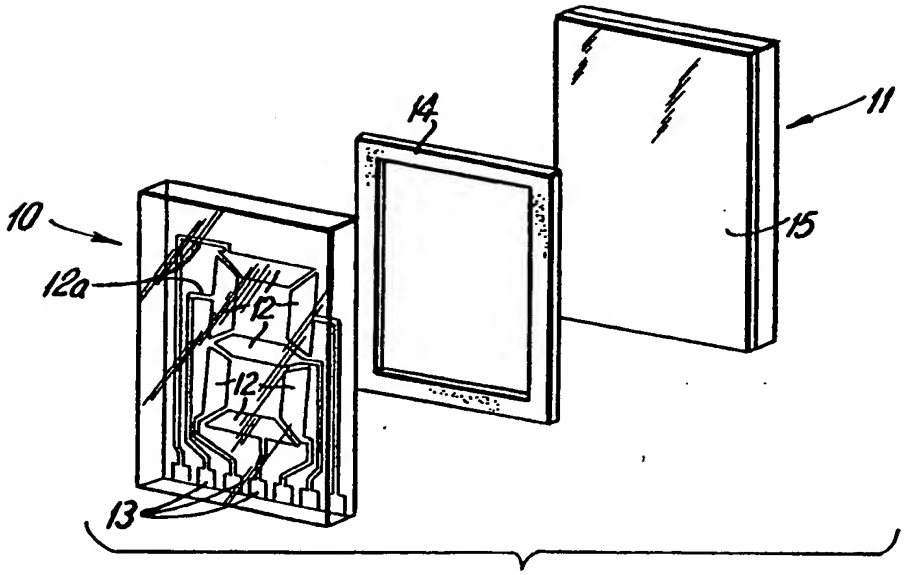

FIG.1

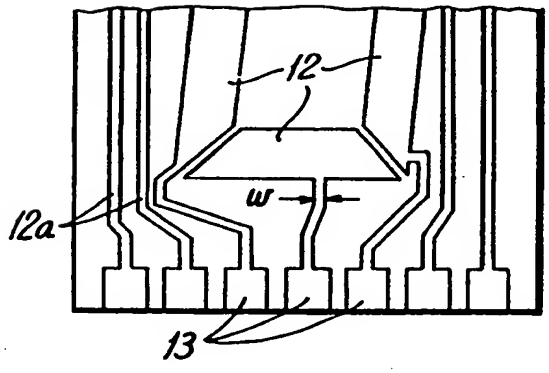

FIG.2

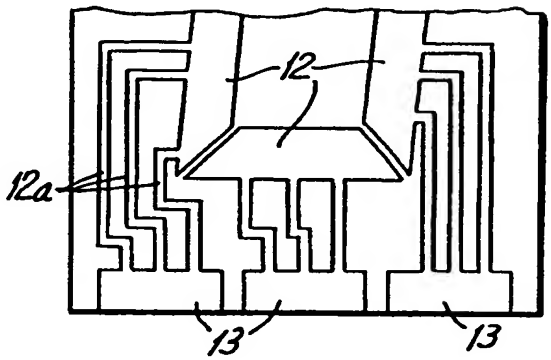

FIG.3

SPECIFICATION

Liquid crystal display and method for making same

The present invention relates to a crystal display and to a method for its construction.

Prior art electro-optic displays of the liquid crystal type typically include a front transparent substrate having a plurality of selectively actuable transparent electrode segments and associated electrode leads thereon, a rear substrate spaced from the front substrate and carrying a counter electrode and a liquid crystal material capable of undergoing optical transformations upon the application of a suitable electrical potential between the electrodes on the front and rear substrates. In the past, it has been common in the manufacture of such displays to pattern or etch the counter electrode so that its outline corresponds closely to that of the character or digit formed by the selectively actuable electrode segments, thereby eliminating overlap between the counter electrode and uninsulated electrode leads and the attendant generation of unwanted optical effects in the liquid crystal material therebetween when an electric field is applied via the leads and electrodes. Of course, patterning or etching of the counter electrode to preclude overlap requires that care be exercised during assembly of the front and rear substrates to ensure that exact alignment of the patterned or etched counter electrode and the character or digit formed by the electrode segments in opposed relationship is achieved. For example, see the Ferguson Patent U.S. No. 3, 731,986 issued May 8, 1973; Fujita Patent U.S. No. 3,781,863 issued December 25, 1973; Ferguson Patent U.S. No. 3,853,392 issued December 10, 1974; Harsch Patent U.S. No. 3,857,627 issued December 31, 1974; Strong Patent U.S. No. 3,857,628 issued December 31, 1974 and the Hsich et al Patent U.S. No. 3,902,790 issed September, 1975.

Representative of a different approach to the construction of liquid crystal displays are the Creagh Patent U.S. No. 3,655,270 issued April 11, 1972; Jones et al Patent U.S. No. 3,690,745 issued September 12, 1972; Borden Patent U.S. No. 3,702,723 issued November 14, 1972 and the Jones et al Patent U.S. No. 3,965,030 issued June 22, 1976 in which the electrode leads on the front substrate overlap the counter electrode on the rear substrate but are electrically insulated by coating with an optically transmissive insulating composition so that no unwanted optical effects are produced in the liquid crystal material between the overlap when the display is activated via the leads.

Other Patents which are concerned with liquid crystal display constructions are the Hedman et al Patent U.S. No. 3,674,341 issued July 4, 1972; Castellano et al Patent U.S. 3,674,342 issued July 4, 1972; Huener Patent U.S. No. 3,740,717 issued June 19, 1973; Fujita Patent U.S. No. 3,781,864 issued December 25, 1973 and Masi Patent U.S. No. 3,794,405 issued February 26, 1974.

The present invention seeks to simplify the construction of liquid crystal displays while preserving the quality of the image produced thereby.

In accordance with a first aspect of the invention there is provided a liquid crystal display comprising first and second substrates, each carrying electrode means, and arranged in spaced working relation and, liquid crystal material is disposed between the substrates and operable to produce a visible optical effect to a viewer when an electric field is established between the electrode means, wherein:

(a) the first substrate has a non-segmented counter electrode layer thereon connected to a voltage source, said counter electrode layer defining a first electrode area;

(b) the second spaced substrate has a plurality of selectively actuable transparent electrode segments and associated uninsulated electrode leads for connecting the segments to said voltage source, said electrode segments and leads together defining a second electrode area smaller than said first area so that said leads overlap the counter electrode layer, said overlapping leads each having a width dimension sufficiently minimized so as not to exceed about .001 inch such that even though an electric field is generated between one or more of the leads and the counter electrode layer during activation of the display as a result of said overlap, the optical effect produced in the liquid crystal material therebetween is not visible to the unaided eye of a viewer; whereby said display can be constructed without having to pattern or etch the counter electrode on said first substrate or precisely align it with the electrode segments to avoid overlap with respect to the electrode leads.

Preferably the width dimension of said overlapping electrode leads does not exceed .0007 inch to reduce visibility.

In accordance with a second aspect of the invention there is provided a method for making a liquid crystal display, said method comprising:

(a) providing a first substrate having a non-segmented counter electrode layer thereon, said counter electrode layer defining a first electrode surface area;

(b) providing a second substrate having a plurality of selectively actuable electrode segments and associated uninsulated electrode leads thereon, said electrode segments and leads together defining a second electrode area smaller than the first area so that said

leads will overlap the counter electrode when the substrates are placed in opposed working relation, said overlapping leads each having a width dimension sufficiently minimized so as not to exceed about .001 inch;

(c) providing peripheral spacing and sealing means;

(d) providing liquid crystal material;

(e) assembling the components (a) to (d) in a sandwich construction such that said substrates are in spaced, opposed working relation, said spacing and sealing means is disposed between the substrates around the periphery thereof and said liquid crystal material is disposed in the space bounded by said substrates and spacing and sealing means, whereby the uninsulated electrode leads and counter electrode overlap but nevertheless do not produce a visible optical effect in the liquid crystal material to the unaided eye of a viewer when the display is activated as a result of the minimized width dimension of said leads, thus making patterning or etching of the counter electrode or its precise alignment with the electrode segments to avoid overlap unnecessary.

In the manufacture of the liquid crystal display of the invention, the non-segmented counter electrode can be easily formed on the first substrate as a uniform layer by deposition, spraying and other well known coating techniques. Commercially available glass substrates carrying for example a uniform conductive tin or indium oxide coating thereon are thus usuable in the manufacture of the display without further treatment. Since in the liquid crystal display of the invention optical effects produced in the liquid crystal material by overlap of the uninsulated electrode leads and the counter electrode layer are not visible to the viewer, patterning or etching the counter electrode layer or precisely aligning it with the electrode segments on the second substrate to avoid overlap are totally unnecessary.

In order that the invention may be better understood, an embodiment thereof will now be described by way of example only and with reference to the accompanying drawings in which:–

Figure 1 is an exploded perspective view of a liquid crystal display constructed in accordance with the invention,

Figure 2 is an enlarged plan view of a portion of the front substrate showing the critical width dimension of the electrode leads, and

Figure 3 is an enlarged plan view of a portion of a front substrate showing a plurality of electrode leads of critical width dimension connected to each electrode segment;

Referring now in more detail to the drawings, there is shown in Fig. 1 an exploded view of a liquid crystal display comprising two spaced transparent substrates, front substrate 10 and rear substrate 11, which may be made of such materials as glass, fused quartz and transparent plastics or resins. A spacing and sealing member 14 of glass frit, epoxy and the like is positioned between the substrates around their interior peripheries and liquid crystal material (not shown) is placed in the space formed between the substrates. Many types of liquid crystal materials may be used and will be well known to those skilled in the art. Although not shown, front and rear polarizers and a reflector behind the rear polarizer are usually employed in conjunction with the components just described. Such polarizers and reflectors and their functions are also well known in the art.

The interior, opposed surfaces of the front and rear substrates are coated with transparent, electrically conductive electrode material such as indium oxide or tin oxide. The conductive electrode coating of front substrate 10 is seen to be patterned or etched in the form of a blocked figure eight character consisting of seven spaced electrode segments 12. A portion of the electrode coating extends from each segment to form uninsulated electrode leads 12*a* connecting each segment with an associated electrical terminal 13. As can be seen in Fig. 1, the conductive counter electrode coating 15 on rear substrate 11 is simply a non-segmented rectangular layer, such a coated substrate being commercially available under the designation NESA glass. It is apparent that the surface area of counter electrode layer 15 exceeds that defined by the electrode segments 12 and leads 12a so that the uninsulated leads and counter electrode layer overlap when the substrates are assembled in spaced working relation. An important feature of the device involves sufficiently minimizing the width dimension, *w*, of the overlapping electrode leads so as not to exceed about .001 inch so that even though an electric field is generated between certain activated leads and the counter electrode layer during display operation, the optical effect produced in the liquid crystal material therebetween will be so small in size as not to be observable with the unaided eye of a viewer. Preferably, the width dimension of the overlapping electrode leads does not exceed .0007 inch, a width of about .0003 to about .0007 inch being even more preferred. Electrodes of width dimensions within these values are readily produced by photolithographic techniques. For example, electrode leads having a width dimension of about .0005 inch have been produced by utilizing Kodak 247, or Hunt Type III resists, or Shipley AZ 1350 resist, or others commonly used in electronic micropatterning. Typically, the thickness of the electrode segments, electrode leads and counter electrode layer is from about 1000 to 2000 Å. Although typical prior art electrode leads have similar thickness, their width dimension is usually about .010 to .020 inch,

never being below .005 inch in width.

Of course terminals 13 are connected to appropriate electrical circuitry (not shown) for selectively actuating the electrode segments for display purposes. For time display purposes, such as in an electronic wristwatch, four liquid crystal displays of the type shown in Fig. 1 are placed side by side or are fabricated as a one-piece unit to provide a complete time display.

The above-described device results in considerable simplification in manufacturing liquid crystal displays and in corresponding cost reductions. For example, no patterning or etching of the counter electrode layer is required thus avoiding overlap with uninsulated electrode leads and resulting unwanted optical effects. The rear substrate and counter electrode are commercially available as NESA glass and can be utilized without additional treatment, other than possible cutting size. During assembly of the display components, no X–Y alignment is required and thus assembly can be accomplished more quickly with fewer rejected assemblies.

A plurality of uninsulated leads 12*a* of critical minimized width dimensions are connected to each electrode segment from its corresponding terminal 13, Fig. 3. The provision of such multiple leads to each electrode segments not only lowers the input resistance but also enhances the reliability of the display electrode circuit without creating unwanted optical effect.

In a typical manufacturing sequence the following steps are involved:

1. Application of photo resist to array size tin or indium oxide coated glass substrate
2. Drying of photo resist
3. Exposure of photoresist tahrough array mask for multiple display patterning
4. Development of patterns
5. Etch unwanted tin or indium oxide
6. Strip off resist
7. Apply frit seal patterns to array and prefire
8. Scribe and break individual patterned glass plates
9. Scribe and break non patterned counter electrode plates
10. Apply a surface agent to glass substrates to ensure proper alignment of liquid crystal material when the display is filled
11. Assemble patterned with unpatterned electrode plates and fuse together
12. Fill with liquid crystal material
13. Seal fill opening.

It will be apparent to those skilled in the art that various modifications could be made to the above-described device. For example, the device has been described with respect to a front substrate carrying the selectively actuable electrode segments 12 and leads 12a and a rear substrate carrying the counter electrode layer 15. In fact, the sequence could be reversed so long as a transparent electrode layer is employed on the front substrate.

There has been described a liquid crystal display device in which the need for exact alignment between the counter electrode and the character or digit formed by the selectively actuable electrode segments is eliminated. The device also eliminates the need for electrically insulating electrode leads which overlap the counter electrode to avoid unwanted optical effects. The device also enables improved appearance of a non-actuated display by making the leads less visible.

CLAIMS

1. A liquid crystal display comprising first and second substrates, each carrying electrode means, and arranged in spaced working relation, liquid crystal material is disposed between the substrates and operable to produce a visible optical effect to a viewer when an electric field is established between the electrode means, wherein:

(a) the first substrate has a non-segmented counter electrode layer thereon connected to a voltage source, said counter electrode layer defining a first electrode area;

(b) the second spaced substrate has a plurality of selectively actuable transparent electrode segments and associated uninsulated electrode leads for connecting the segments to said voltage source, said electrode segments and leads together defining a second electrode area smaller than said first area so that said leads overlap the counter electrode layer, said overlapping leads each having a width dimension sufficiently minimized so as not to exceed about .001 inch such that even though an electric field is generated between one or more of the leads and the counter electrode layer during activation of the display as a result of said overlap, the optical effect produced in the liquid crystal material therebetween is not visible to the unaided eye of a viewer; whereby said display can be constructed without having to pattern or etch the counter electrode on said first substrate or precisely align it with the electrode segments to avoid overlap with respect to the electrode leads.

2. A liquid crystal display according to claim 1 wherein the width dimension of said overlapping electrode leads does not exceed .0007 inch to reduce visibility.

3. A liquid crystal display according to either one of claims 1 or 2 wherein the non-segmented counter electrode layer is a simple rectangle in shape.

4. A liquid crystal display according to any one of claims 1, 2 or 3 wherein the electrode segments define a multiple segment character on the substrate.

5. A liquid crystal display according to claim 4 wherein the multiple segment character is a blocked figure eight character.

6. A liquid crystal display according to any one of the preceding claims wherein said first and second substrates are the rear and front substrates of the display, respectively.

7. A liquid crystal display device substantially as hereinbefore described with reference to the accompanying drawings.

8. A method for making a liquid crystal display, said method comprising:

(a) providing a first substrate having a non-segmented counter electrode layer thereon, said counter electrode layer defining a first electrode surface area;

(b) providing a second substrate having a plurality of selectively actuable electrode segments and associated uninsulated electrode leads thereon, said electrode segments and leads together defining a second electrode area smaller than the first area so that said leads will overlap the counter electrode when the substrates are placed in opposed working relation, said over lapping leads each having a width dimension sufficiently minimized so as not to exceed about .001 inch.

(c) providing peripheral spacing and sealing means;

(d) providing liquid crystal material;

(e) assembling the components (a) to (d) in a sandwich construction such that said substrates are in spaced, opposed working relation, spacing and sealing means is disposed between the substrates around the periphery thereof and said liquid crystal material is disposed in the space bounded by said substrates and spacing and sealing means, whereby the uninsulated electrode leads and counter electrode overlap but nevertheless do not produce a visible optical effect in the liquid crystal material to the unaided eye of a viewer when the display is activated as a result of the minimized width dimension of said leads, thus making patterning or etching of the counter electrode or its precise alignment with the electrode segments to avoid overlap uncecessary.

9. The method of claim 8 wherein the first substrate has a simple rectangular counter electrode layer formed thereon by deposition of a conductive transparent film on a substrate.

10. The method according to either one of claims 8 or 9 wherein the width dimension of said electrode leads does not exceed about .0007 inch.

11. The method according to any one of claims 8, 9 or 10 wherein the electrode segments are formed into a blocked multiple segment character on the substrate character.

12. The method according to claim 10 wherein the multiple segment character is a blocked figure eight character.

13. A method for making a liquid crystal display as claimed in claim 8, substantially as hereinbefore described.

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